VII. STORM DAMAGE VULNERABILITY ANALYSIS UPDATE

The May 2019 beach profile survey data were used to update the previously completed storm damage vulnerability analysis for the Town of Duck. The analysis utilized the Storm Induced Beach Change Model, SBEACH, developed by Larson and Kraus (Larson and Kraus, 1989) for the US Army Corps of Engineers (USACE). SBEACH is a two-dimensional model, which simulates changes in the beach profile that could result from coastal storms of varying intensity in terms of storm tide levels, wave heights, wave periods, and storm duration. Input data required by SBEACH includes beach cross-sections, the median sediment grain size, several calibration parameters, a temporally varying storm hydrograph (wave height, wave direction, wave period, and water surface elevation) and wind field (wind speed and direction).

Simulated beach profile changes that result from varying storm waves and water levels include the formation and movement of morphological features such as longshore bars, troughs, berms, and dunes. SBEACH assumes that the simulated profile changes are produced only by cross-shore processes, while longshore sediment transport processes are neglected. This empirically based numerical model was formulated using both field data and the results of large-scale physical model tests. Simulated profile changes are driven by the cross-shore variation in wave height and wave setup calculated at discrete points along the profile from the offshore zone to the landward survey limit.

The following basic assumptions underlie the SBEACH model:

- Breaking waves and variations in water level are the major causes of sand transport and profile response.
- The median sediment grain diameter along the profile is reasonably uniform across shore.
- The shoreline is straight (i.e. longshore effects are negligible during the term of simulation).
- Linear wave theory is applicable everywhere along the beach profile.

SBEACH is the same model used in the original Erosion and Shoreline Management Feasibility Study (CPE-NC, 2013), the Town of Duck Erosion and Shoreline Management Engineering Design Report (CPE-NC, 2015). Information on model calibration can be found in the original feasibility report (CPE-NC, 2015). The original feasibility study used beach profile data from 2013; and an update was conducted in 2016, (CPE-NC, 2016), which used beach profile data from 2015. This report describes the latest update to assess storm vulnerability with SBEACH using the May 2019 survey as the initial conditions.

During the design analysis for the Duck Beach Nourishment project, an extensive analysis was completed to determine whether a scaled hurricane or nor'easter should be used for design purposes (CPE-NC, 2015). Review of historic data indicated that scaling all storm parameters to create synthetic storms results in conditions that do not represent natural occurrences. Using a method such as this may be appropriate for a quick study to investigate project feasibility but could ultimately result in an over- or underestimate of project need and performance. As a result, actual storm characteristics were reviewed to select storms that best matched extreme event characteristics. Considering that the storm hydrograph is the primary model driver, the top wave

height and storm surge events were compared with the calculated return period descriptors. The Perfect Storm best represented a 3-year event, Hurricane Sandy resembled a 5-year event, and Hurricane Isabel may best describe a 25-year event. Considering a goal of the project was to provide a reasonable level of storm damage reduction, Hurricane Isabel was adopted as the design storm. The 2019 analysis used the same Hurricane Isabel storm characteristics to determine vulnerability during 2015 analysis with the exception of updating the Hurricane Isabel water level to 2019 to account for relative sea level rise. The increase in water level was computed based on the rate of relative sea level rise measured at the NOAA Tide Gauge (Station ID 8651370) located at the USACE FRF Pier in Duck, NC and multiplied by 16 years; the number of years that have passed since Hurricane Isabel made landfall in North Carolina.

The results of the SBEACH simulations were used to identify structures that could be impacted during the design storm events. A 1-foot change in profile elevation is a reasonable threshold for estimating when structures become vulnerable to wave damage, including undermining and/or inundation (USACE, 1985). Therefore, a structure is considered vulnerable if any part of the structure is seaward of the landward most location where the profile is lowered by 1 foot. For this study, the landward most location where the profile is lowered by 1 foot is extracted from model results along profiles to identify *impact points*. These *impact points* are then connected to create an *impact line* that is used to identify structures damaged between profiles. The resulting May 2019 impact lines, in addition to those obtained using the September 2013 profile survey, and May 2015 profile survey, are provided in Appendix B.

As summarized in Table 5, the updated May 2019 analysis showed that 104 structures and 26 pools were no longer identified as vulnerable compared to the May 2015 conditions. In May 2015, prior to the 2017 beach nourishment project, the analysis of the area north of the USACE FRF property indicated there were 89 structures and 29 pools identified as vulnerable within the Project Area (D-10 to D-19). **According to the updated analysis of the May 2019 conditions, the number of structures and pools identified as vulnerable has been reduced to 0 within the Project Area. There was only one structure identified in the updated analysis as vulnerable along northern 3.3 miles of the Duck shoreline and it was located outside of the Project Area as shown in Table 5.**

The analysis of the Town of Duck shoreline south of the USACE FRF property (D-23 to D-34) also indicated a reduction in the number of identified vulnerable structures from May 2015 to May 2019, decreasing from 43 structures to 28 structures, respectively, and equivalent to a 35% reduction. However, the total number of pools identified as vulnerable south of the USACE FRF property did not change from 2015 to 2019. The largest reduction in the number of vulnerable structures south of the FRF property occurred between stations D-25 (Olde Duck Rd) and D-27 (Wampum Dr.) believed to be attributed to a large gain of sand on the profile at station D-26 (Cook Dr.). However, the updated analysis indicates the area located between D-27 (Wampum Dr.) to D-30 (Four Seasons Lane) has maintained the largest number of vulnerable structures and pools when compared to the May 2015 conditions. This area correlates with long-term shoreline recession rates included in Table 3 and erosion rates as illustrated in Figure 5.

Table 5. Storm Damage Risk – Existing Conditions

Profile		Storm Damage Risk Sept. 2013 Conditions		Storm Damage Risk May 2015 Conditions		Storm Damage Risk May 2019 Conditions	
From	To	Structure	Pool	Structure	Pool	Structure	Pool
D-01	D-02	0	0	0	0	0	0
D-02	D-03	0	0	0	0	0	0
D-03	D-04	0	0	0	0	0	0
D-04	D-05	1	0	0	0	1	0
D-05	D-06	0	0	0	0	0	0
D-06	D-07	0	0	0	0	0	0
D-07	D-08	0	0	0	0	0	0
D-08	D-09	0	0	0	0	0	0
D-09	D-10	0	0	1	0	0	0
D-10	D-11	4	0	9	0	0	0
D-11	D-12	9	1	9	1	0	0
D-12	D-13	10	4	9	4	0	0
D-13	D-14	10	1	10	1	0	0
D-14	D-15	13	6	11	6	0	0
D-15	D-16	13	6	12	6	0	0
D-16	D-17	11	5	12	5	0	0
D-17	D-18	11	6	11	6	0	0
D-18	D-19	5	0	6	0	0	0
D-19	D-20	0	0	0	0	0	0
D-20	D-21	0	0	0	0	0	0
D-21	D-22	0	0	0	0	0	0
D-22	D-23	0	0	0	0	0	0
D-23	D-24	0	0	0	0	0	1
D-24	D-25	0	0	0	0	0	0
D-25	D-26	3	2	7	2	1	0
D-26	D-27	0	2	5	2	0	3
D-27	D-28	0	2	0	6	1	6
D-28	D-29	6	7	13	7	13	7
D-29	D-30	1	4	3	4	4	7
D-30	D-31	0	3	1	3	0	3
D-31	D-32	4	7	5	7	3	7
D-32	D-33	1	3	5	4	5	4
D-33	D-34	1	4	4	5	1	2
D-01	**D-34**	**103**	**63**	**133**	**69**	**29**	**40**

Note this analysis only identified which structures could experience damage due to storm induced erosion caused by a storm having predetermined storm characteristics which mimic those measured during Hurricane Isabel. The analysis did not include an evaluation of damages due to flooding, wave impacts, or wind nor does it quantify the economic impacts resulting from the damage or loss of such structures.